

Relationship Between Mercury Content of Hair and Amount of Fish Consumed

SEIYA YAMAGUCHI, M.D., HISAO MATSUMOTO, Ph.D., SACHIKO MATSUO, B.S.,
SHUNSUKE KAKU, M.D., and MICHIO HOSHIDE, B.S.

A GREATER amount of mercury has been found in the scalp hair of the Japanese than in the scalp hair of Americans living either in Japan or in the United States (1). The reason has been attributed to the abnormal exposure of the Japanese to mercurial pesticides used for agricultural purposes. Recent investigations to determine the amount of mercury in human scalp hair have suggested a positive correlation with the intake of alkylmercury compound in foods (2, 3).

Several observations on the amount of methylmercury in marine products also have been reported (4, 5). Consequently, arguments concerning the allowable concentration of mercury in foods have arisen (6).

While extensive studies of the amount of mercury in marine products have not yet been reported, data on the mercury content of a limited number of spe-

cies of fish and shellfish eaten by the Japanese are given in table 1.

We have attempted to study how the mercury compound in marine products influences mercury metabolism in the bodies of persons living in different environments who have different food habits.

The design of the study was influenced by the following premises.

1. The mercury content of scalp hair will increase according

Dr. Yamaguchi is professor and director of the department of public health, Kurume University School of Medicine. Dr. Matsumoto is an assistant professor, and Miss Matsuo, Dr. Kaku, and Miss Hoshide are research associates at the school. Tearsheet requests to Seiya Yamaguchi, M.D., Kurume University School of Medicine, 67 Asahimachi, Kurume-shi, Japan.

to the intake of methylmercury compounds (2).

2. Fish caught in an area where alkylmercury compounds are known to pollute the water contain a large amount of mercury (7); 40 to 90 percent of the fish's total mercury content is composed of methylmercury compound.

3. It is recognized that fish caught in unpolluted natural waters contain a certain amount of methylmercury compound. The amount fluctuates according to the size and age of the fish and as yet undetermined biological characteristics of fish.

Materials and Methods

Hair samples were collected from persons in several parts of the world to test the hypothesis that the amount of mercury in scalp hair will correlate with the amount of fish consumed. It is recognized that consumption of

fish and shellfish varies from country to country. Japanese have the highest consumption—84 grams per day—Americans consume 17 grams and Pakistanis, 5 grams per day (8).

Hair samples were obtained from four groups of Japanese and a small group of Americans living in Fukuoka. One of the authors and research associates of the department on assignments in various parts of the world collected the remaining samples.

Samples were obtained from the following groups.

- 178 Japanese living in Fukuoka on the main island of Kyushu, selected at random. They had no abnormal exposure to mercury via occupational sources, medicines, pesticides, cosmetics, or other suspected sources of mercury contamination.

- 89 Japanese males, mostly fishermen working for a deep sea tuna factory on the small island of Ikitsuki, about 10 miles from Kyushu in the Sea of Genkai. The Ikitsuki islanders consumed more

fish than the Fukuoka residents. On the basis of a 10-day observation period, it is estimated that about 90 grams of fish were consumed per meal, or about 270 grams per day for those eating fish at every meal.

- 33 patients of a Kyushu psychiatric hospital. They ate fish less than once a day, less frequently than most Japanese.

- 27 residents of an almshouse on Kyushu. They consumed less fish than the residents of Fukuoka, about 60 to 70 grams per day or less.

- 14 American medical officers living at a Fukuoka air base. These men ate fish three to four times a week at the hospital canteen or at home. Occasionally some of them ate sushi (raw fish).

- 10 Okinawans, all males. The Okinawans eat about the same amount of fish as the people of Fukuoka, fish and pork being their major sources of protein.

- 7 residents of Cleveland, Ohio. All were white male Amer-

icans. No data were available on their consumption of fish.

Table 1. Mercury and methylmercury content of representative species of fish and shellfish

Species and sample No.	Total mercury (p.p.m.)	Methylmercury (p.p.m.)
Gray mullet:		
1.....	0.052	0.001
2.....	.116	.001
3.....	.024	N.D.
Konosirus punctatus:		
1.....	.003	.001
2.....	.039	N.D.
3.....	.031	N.D.
Octopus:		
1.....	.038	N.D.
2.....	.003	.001
Shellfish (asari):		
1.....	.064	.001
2.....	.166	.004
3.....	.021	N.D.
Shellfish (mogai):		
1.....	N.D.	N.D.
2.....	.002	.001
Crab:		
1.....	.148	.002
2.....	.042	.011
Tunafish:		
1.....	.649	.....
2.....	.060	.....
3.....	.478	.....
4.....	.196	.....
5.....	.833	.730

NOTE: N.D.—not detected.

Table 2. Mercury content of scalp hair of residents of Fukuoka, Japan

Age group (years)	Samples with mercury content (p.p.m.) of—										Total samples	Average mercury
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	10-11	11 or more		
Total.....	6	24	36	36	30	23	8	8	1	6	178	¹ 3.94
Male.....	5	5	23	23	18	18	6	7	1	5	111	² 4.35
6-15.....		1	2	.....	1	1	1	.....			6	3.59
15-20.....		1	3	3	4	1	1	2			15	4.26
20-30.....	1	2	7	5	4	3	1	1		1	25	3.92
30-40.....	2	.....	4	6	4	6	.....	3	1	3	29	5.26
40-50.....	1	1	3	4	2	3	2	1		1	18	4.30
50-60.....	1	.....	4	5	3	4	1	.....			18	3.79
Female.....	1	19	13	13	12	5	2	1		1	67	³ 3.25
6-15.....		3	.....	1	2	1	.....				7	3.37
15-20.....		4	1	4	4	1	1	.....		1	16	4.03
20-30.....		3	5	3	1	1	.....				13	2.89
30-40.....	1	4	5	1	1	1	1	1			15	2.95
40-50.....		3	1	.....	2	1	.....				7	2.78
50-60.....		2	1	4	2	.....					9	3.20

¹ Standard deviation 2.37.

² Standard deviation 2.45.

³ Standard deviation 2.02.

NOTE: No samples showed values between 8 and 10 p.p.m.

• 45 residents of Silgarhi Doti and Dhangarhi, Nepal. (One of the authors, on assignment there, observed that the Nepalese ate no fish at all during his 45-day stay).

All the subjects were presumably healthy; no one mentioned having any diseases when interviewed. Samples were generally taken from the top of the scalp and washed twice with detergent (sodium salt of alkyl benzene sulfonic acid) and rinsed twice with water.

To measure the total mercury in the hair samples we followed the cold vapor atomic absorption procedure used by Yamaguchi

and Matsumoto in a previous study (9). Methylmercury was identified and determined by gas chromatography equipped with an electron capture detector (10). Thin-layer chromatography has also been used as a supplementary procedure (11).

Results

Comparison of Japanese hair samples. Table 2 shows the mercury content of hair samples from the residents of Fukuoka. This group consisted of 111 males and 67 females. Their ages ranged from 6 to 60 years. The

average concentration for this group, who consumed an amount of fish normal for Japanese, was 3.94 p.p.m. with a standard deviation of 2.37 p.p.m.

The amount of mercury in the hair samples from males was apparently greater than in the samples from females. Consumption of larger amounts of fish may explain the difference. We also speculated, however, that because Japanese males tend to use sticky hair creams and wash their hair less frequently than females, mercury contamination by air pollutants may cause the difference.

Table 3. Mercury content of scalp hair of male residents of Ikitsuki Island, Japan

Age group (years)	Samples with mercury content (p.p.m.) of—											Total samples	Average mercury	
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11			11 or more
Total mercury.....		6	16	13	17	11	8	9	4	2	1	2	89	¹ 4.83
6-15.....		2	2	1									5	2.43
15-20.....		3	4	1	6	3		4		1			22	4.41
20-30.....		1	8	6	4	4	5	2	3	1		1	36	5.08
30-40.....			1	2	5	3	1	3	1				15	5.12
40-50.....			1	1	2		2					1	7	5.57
50-60.....				2		1					1		4	5.63
Methylmercury chloride..	2	27	32	16	5	5	1	1					89	² 2.73
6-15.....		4	1										5	1.78
15-20.....	1	6	10	3	1	1							22	2.55
20-30.....	1	12	12	4	3	3	1						36	2.74
30-40.....		1	6	6	1	1							15	3.25
40-50.....		3	2	2									7	2.36
50-60.....		1	1	1				1					4	3.73

¹ Standard deviation 2.31.

² Standard deviation 1.27.

Table 4. International comparison of total mercury content of scalp hair

Nationality and sex	Location	Number in sample	Mean mercury (p.p.m.)	Standard deviation	t-test
A-Japanese male.....	Fukuoka, Kyushu.....	111	4.35	2.45	
B-Japanese female.....	Fukuoka, Kyushu.....	67	3.25	2.02	
C-Japanese male.....	Ikitsuki Island.....	89	4.83	2.31	
D-Japanese male.....	Okinawa.....	10	4.56	1.71	
E-Japanese male.....	Psychiatric hospital, Kyushu.....	12	2.09	.92	A:E t=3.16, P<0.01
F-Japanese female.....	Psychiatric hospital, Kyushu.....	21	2.02	.61	B:F t=2.74, P<0.01
G-Japanese male.....	Almshouse, Kyushu.....	17	2.02	1.27	A:G t=3.16, P<0.01
H-Japanese female.....	Almshouse, Kyushu.....	10	1.63	1.02	B:H t=2.74, P<0.01
I-American male.....	Kyushu.....	14	1.89	1.04	A:I t=3.71, P<0.001
J-American male.....	Cleveland, Ohio.....	3	2.41	1.32	
K-American female.....	Cleveland, Ohio.....	4	1.61	.32	
L-Nepalese male.....	Silgarhi Doti and Dhangarhi.....	31	.163	.187	A:L t=9.50, P<0.001
M-Nepalese female.....	Silgarhi Doti and Dhangarhi.....	14	.457	.484	B:M t=5.12, P<0.001

Table 3 shows the mercury content in the samples from Ikitsuki islanders. The amount of mercury apparently increased with age; no such increase was apparent among the Fukuoka residents.

Several factors may figure in this age change. The Ikitsuki islanders are a homogeneous iso-

lated group while the persons in the table 2 sample were selected at random from a population of about half a million. Also the air in Fukuoka is contaminated by several pollutants, and mercurials in dust and soot may have affected the city dwellers' hair. Although hair samples were washed before they were meas-

ured for mercury content, some may have been affected by factors other than gastrointestinal absorption of mercury from marine products. In contrast, the air in Ikitsuki is relatively unpolluted; the tuna factory is the only industry on the island.

International comparison.
Consumption of fish varies from

Table 5. Mercury content of scalp hair of male residents of Ikitsuki Island, Japan, by age group and fish consumption

Age group and mercury content (p.p.m.)	Fish at every meal		Fish once a day or less	
	Total mercury	Methyl mercury	Total mercury	Methyl mercury
10-20 years.....	14	13	14	14
0-1.....	0	0	0	1
1-2.....	0	2	5	8
2-3.....	2	8	4	3
3-4.....	0	1	2	2
4-5.....	5	1	1	0
5-6.....	3	1	1	0
6-7.....	0	0	0	0
7-8.....	3	0	1	0
8-9.....	0	0	0	0
9-10.....	1	0	0	0
10 or more.....	0	0	0	0
20-30 years.....	22	19	21	17
0-1.....	0	0	0	1
1-2.....	0	3	1	9
2-3.....	0	8	9	4
3-4.....	2	2	4	2
4-5.....	4	3	2	0
5-6.....	3	2	2	1
6-7.....	5	1	1	0
7-8.....	4	0	0	0
8-9.....	2	0	1	0
9-10.....	1	0	1	0
10 or more.....	1	0	0	0
30 years or more.....	20	20	6	6
0-1.....	0	0	0	0
1-2.....	0	4	0	1
2-3.....	1	6	1	3
3-4.....	5	7	0	2
4-5.....	4	1	3	0
5-6.....	3	1	1	0
6-7.....	3	0	0	0
7-8.....	2	1	0	0
8-9.....	0	0	1	0
9-10.....	0	0	0	0
10 or more.....	2	0	0	0
All ages.....	56	52	41	37
0-1.....	0	0	0	2
1-2.....	0	9	6	18
2-3.....	3	22	14	10
3-4.....	7	10	6	6
4-5.....	13	5	6	0
5-6.....	9	4	4	1
6-7.....	8	1	1	0
7-8.....	9	1	1	0
8-9.....	2	0	2	0
9-10.....	2	0	1	0
10 or more.....	3	0	0	0

NOTE: Total mercury was measured in 97 hair samples, methylmercury in 89.

country to country because of dietary habits and availability of fish and shellfish. Table 4 presents values for various groups of Japanese as well as for groups from other countries. Values for the inpatients of the psychiatric hospital, who had eaten fish less than once a day, were significantly smaller than those for the Japanese who ate the usual amount of fish (t -test ≤ 0.01 level).

No methylmercury was detected in the hair samples from the Nepalese, who supposedly eat very little fish.

Testing the hypothesis. The samples from the Ikitsuki males showed the largest concentration of mercury. They were divided into two groups according to the amount of fish intake, and the mercury content in their hair samples was statistically compared. Tables 5 and 6 show the distribution by age group of total mercury and methylmercury.

In all three age groups, there was a statistically significant difference in the mean values for those who ate fish at every meal and those who ate it once a day or less (table 6). The difference in the amount of total mercury and methylmercury chloride in the group over 30 years was not

statistically significant. The people in this group could not be clearly classified into two groups because they could not remember how much fish they had eaten. However, the accumulation of mercury in hair increased with age (table 3).

Comments

Persons responsible for public health measures have an urgent assignment to establish a maximum allowable value of mercury in foods. As the threshold limit of organic and inorganic mercury compounds in a working environment has been clearly defined (12), so the maximal allowable concentration of total mercury and alkylmercury in foods should be clearly defined. Obviously, the smaller the content of carbon in an alkyl structure, the stronger the toxicity and the slower the excretion from a biological milieu.

The amount of mercury in a hair sample can be used as a diagnostic criterion in mercury poisoning, particularly in alkylmercury poisoning. In a report (2) on the rate of increase of mercury content in hair after administering various kinds of mercurials, it was concluded that

the rate of increase was largest after the administration of alkylmercury compound. Arylmercury and mercuric chloride contributed almost nothing to the increase of mercury content in the hair of experimental animals (2).

It is well known that fish and shellfish contain certain amounts of mercury compound that originate from artificial or unknown natural sources. The mercury compound contained in marine products consists of methylmercury from 40 to 90 percent or more of total mercury. The metabolic transformation of mercury compound in fish, if inorganic mercury is transformed into alkylmercury in the biological milieu, is a puzzle at the moment.

If the methylmercury is accumulated and concentrated through a food chain cycle, its occurrence and reservoir or source in seawater, regardless of artificial or natural origin, should be determined. We suggest that the amount of fish consumed significantly influences the mercury content in scalp hair, particularly the methylmercury content. The actual effect of alkylmercury from fish caught in a natural environment on the health of people will have to be examined in detailed,

Table 6. Mean and standard deviation of total mercury and methyl mercury values and t -test results, by age group and fish consumption of male residents of Ikitsuki Island, Japan

Age group and fish consumption	Mean		Standard deviation		t -test results	
	Total mercury	Methylmercury	Total mercury	Methylmercury	Total mercury	Methylmercury
10-20 years:						
Fish at every meal	5.30	2.97	2.15	1.10	} $t=3.26, P<0.01$	$t=3.10, P<0.01$
Fish once a day or less	2.92	1.88	1.69	.70		
20-30 years:						
Fish at every meal	6.37	3.30	1.93	1.35	} $t=4.12, P<0.001$	$t=2.98, P<0.01$
Fish once a day or less	3.91	2.10	1.99	1.08		
30 years and over:						
Fish at every meal	5.47	3.18	2.28	1.46	} $t=0.62, P<0.6$	$t=0.64, P<0.6$
Fish once a day or less	4.83	2.78	1.89	.75		
All persons:						
Fish at every meal	5.78	3.17	2.13	1.31	} $t=4.91, P<0.001$	$t=4.01, P<0.001$
Fish once a day or less	3.71	2.15	1.94	.98		

intensive studies, which should be undertaken immediately.

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Purpose of the study was to clarify the relationship between the amount of mercury in scalp hair and the amount of seafood consumed. The study was based on two premises.

1. The amount of mercury in scalp hair will increase according to intake of methylmercury from marine products.

2. The amount of mercury in hair of groups of persons who have different religious or dietary customs concerning consumption of marine products will also differ.

Mercury in the scalp hair of 178 residents of Fukuoka, Japan, was measured. They had had no abnormal exposure to occupational sources, medicines, pesticides, cosmetics, and other suspected sources of mercury contamination. The mean mercury content in hair samples of 111 males was 4.35 p.p.m. with a standard deviation (S.D.) of 2.45 p.p.m. For 67 females the average amount of mercury was 3.94 p.p.m., S.D. 2.03 p.p.m. The Fukuoka residents ate about an average amount of fish for Japanese, 84 grams per day.

The average mercury content in 89 hair samples of male Ikitsuki islanders (mostly fishermen working for a tuna fishing company) was 4.83 p.p.m. with an S.D. of 2.31 p.p.m. The amount of mercury apparently increased with age; no such increase was apparent among the Fukuoka residents.

The amount of mercury in the scalp hair of 14 American men living in Japan was 1.89 p.p.m. with 1.04 p.p.m. S.D. Mercury content of samples from seven Americans in Cleveland, Ohio, was, for three males, 2.41 p.p.m. (S.D. 1.32 p.p.m.) and for four females, 1.61 p.p.m. (S.D. 0.32 p.p.m.). Hair samples from Nepalese living in Silgarhi Doti and Dhangarhi were collected and measured. The average amount for 31 males was 0.163 p.p.m. with 0.187 p.p.m. S.D., and that for 14 females was 0.457 p.p.m. with 0.484 p.p.m. S.D. They ate no fish during the survey period.

The amount of methylmercury in the samples was 57 percent of the total mercury content.